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Improving Sustainability Concept in Developing Countries (ISCDC)

Straw Wastes from an Environmental Disaster to ECO-Board towards a Sustainable Urban Environment

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Abstract

The purpose of this paper is to develop an economical, sustainable, and environmentally friendly straw Medium Density Fiber board (MDF) process, capable of full-scale manufacturing and to produce ECO-MDF boards of requested quality. The investigated straw was based on rice. In the environmental perspective the agricultural straw-waste is a suitable source for producing MDF to avoid open field burning and to capture carbon dioxide (CO2). Additionally, the straw ECO-MDF panels can be used in the architecture and urban design as a material in furniture or hardscape manufacture.

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Keywords: Sustainable urban environmrnt , Eco-friendly boards , straw wastes, Recycling ,MDF,MDI

1. Introduction

The industrial process is considered one of the advanced technology methods to take advantage of agricultural crops waste or its recycling. It is play a major role in the upgrading of national income in addition to the positive impact on the preservation of environment, especially in the developing countries because of the followed methods of improper disposal of this wastes pollution.

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A product that is sustainable can be continuously renewed and does not rely on extracting material from the earth's natural resources. Sustainable urban design is the process that investigates and experiments ways in which we can use more sustainable products. A sustainable site incorporates renewable, local, and low-energy input landscape materials and avoids materials, products, and practices that are harmful to the environment.

2-Straw burning problem: - Straw burning is done to eliminate sources of insect pests, rat infestation and control of rice diseases. This is because the rice is continuously worked on the farm which do not eliminate the life cycle of insects and hence the diseases. In fact, the burning of straw also facilitates plowing and leveling the ground which saves time for land management for the next crop season. (1) In essence, the burning of straw will cause air pollution, including producing 13 tons per hectare of carbon dioxide. Suspended particles harm the lungs and the main cause of respiratory disease. In addition, incomplete and inefficient combustion will produce carbon monoxide and carcinogenic hydrocarbons that can cause cancer. (2) Combustion of one ton of rice straw will produce 3 kg of particulate material, 60 kg of carbon monoxide, 1460 kg of carbon dioxide, 199 kg of dust and 2 kg of sulfur dioxide. These gases play an important role to affect the atmosphere and the environment and thus lead to global climate change. (9)

3-Research aim and objectives: - The research seeks to get rid of straw waste in a sustainable way by presenting a proposal of how to convert straw wastes into a sustainable MDF to be used in architecture and urban design such as furniture, pedestrian, seats, decks … etc.

4-Research Methodology

Research methodology is based on qualitative study upon three approaches; theoretical, analytical and applied study. The theoretical study tends to identify the impact of burning rice straw on urban environment and how to use rice straw to produce an environmentally friendly product, and discover the Economic and Environmental aspects of straw MDF manufacture. This is followed by an analytical study of straw MDF factory in Egypt to identify the harmful glue material (urea formaldehyde) used by the factory to produce MDF panels. This is followed by an applied study about how to use a sustainable glue material (MDI) to produce ECO MDF boards and the methods used in urban and architecture design.

5- The impact of burning rice straw on the black cloud in Egypt

After the rice harvest each autumn, Egyptians take a deep breath and brace for the "black cloud", a thick layer of smog from burning rice straw that spreads across Cairo and the Nile valley for several weeks.

* Egypt generates 30 million tons of agricultural waste a year
* Burning rice straw emits 80,000 tonnes of carbon dioxide
* Rice straw could fetch as much as $50.25 a tonne
* Plans to convert rice straw into lucrative materials

Environmentalists blame the burning of agricultural "waste", mostly rice straw, for the pall of smoke that turns the capital's already noxious air into an even more toxic mix. (4)

Farmers produce about 30 million tons of what they see as waste each year. Egyptian scientists have been using rice straw in pilot projects to produce a variety of materials from pulp for paper production to active carbon for use in water filters. The Environment Ministry has tried to contain the pollution blight over the past decade by collecting rice straw from some farms for about 45 pounds a tone.it contracted one state and two private firms to collect, press and bale the rice straw. (4)

5-1-- Straw burning and global warming

Straw burning also contributes to global warming through the emission of $C0^2$ and other greenhouse gasses and even impacts on road safety, as the smoke cause's reductions in visibility. CO2 survives in the atmosphere for a long time up to many centuries so its heat-trapping effects are compounded over time. Of the many heat-trapping gases, CO2 puts us at the greatest risk of irreversible changes if it continues to accumulate unabated in the atmosphere as it is likely to do if the global economy remains dependent on fossil fuels for its energy needs. To put this in perspective,

the carbon we put in the atmosphere today will literally determine not only our climate future but that of future generations as well.

6-Towards a Sustainable Urban Environment

In order to develop and maintain sustainable urban environment, new methods and tools are needed to evaluate the environmental quality of the urban fabric.

6-1-Goals and strategies

- Manage resources and materials efficiently by reducing material needs, reusing materials generated onsite, and recycling materials as much as possible.
- Keep and reuse landscape by-products.
- Select and use renewable, local, or low-energy input materials.
- Avoid materials, products, and practices that are harmful to the environment.
-Value the human component and social benefits gained by interaction with gardens and natural spaces.
- Consider human energy and creativity as a renewable resource recognizing the potential for healthy employment conditions.

6-2-Features of Sustainable Materials

We identified three groups of criteria, based on the material life cycle that can be used in evaluating the environmental sustainability of building materials. The presence of one or more of these features in building materials make it environmentally sustainable. (5)

-Local materials are extracted, processed, and manufactured locally, providing support for local economies and reducing energy consumption and transportation costs.

_Identify materials and suppliers that originate locally and are harvested/produced in a sustainable manner (e.g. plants grown in local nurseries)

_Choose materials with regional character to cultivate a sense of place (6)

7- Clear the Fields by using Agricultural Waste Fiber

Straw is the stem of a small grain cereal plant, such as wheat or rice, or the shaft left after the growing of grass for grass seed. While some straw is left to condition the soil, in many places it is cleared from fields after grain harvest by burning, which has caused serious air pollution problems. Using straw as the fiber for PB and MDF provides an alternative to burning straw in fields or disposing of bagasse by burning it in steam boilers. Although processing straw into PB and MDF is similar to processing wood residues, breaking straw into fibers requires less processing and less drying, therefore less energy use.(7)

In addition, the properties of MDF strawboard, such as internal bond strength, resistance to rupture, moisture resistance, and screw holding strength , are better than wood-based PB and MDF because formaldehyde-based resins are not used with MDF board made from straw and bagasse, the resulting product does not carry the health risks associated with formaldehyde.(7)

8-Economical and Environmental aspects of straw MDF manufacture

The specific selection of straw and agriculture wastes as a raw material for refinement of biomass depends on a variety of factors. The most frequent factors mentioned for conversion of straw to bio-ethanol, bio energy and composite boards are based on availability, quality, quantity, removal, transportation, storage, and landowner/producers costs.(7)The main environmental benefits are the reduced open field burning of an annual plant and to capture carbon dioxide (CO2), the biological sink for extended time into MDF panels, instead of converting straw directly into bio energy or applying straw fibre a few times as recycled paper. Additionally, the straw MDF panels can be recycled or converted to energy after utilization. There are two types of straw fibre resources for industrial applications grown in large areas of the world; wheat and rice straw.

The MDF process has essential advantages since it can produce fiberboard from readily available and renewable raw materials. Most of the straw plant can be converted to fiberboard products and the rejected materials can be integrated in the energy system of the MDF mill. (7) The reject from 32 the energy generating system or ash is potentially a substance that can be returned to the farmer and regain essential mineral components to the ecosystem. In the

production of bio energy and also the production of paper products the high silicon and ash content of rice-straw is a profound disadvantage. The silicon in combination with other inorganic components will build up in the chemical recovery system of the pulping process and require special care and extra costs. In bio-energy applications the high ash and silicon content of rice-straw complicate the burning technique and handling of large amounts of ash. Wheat-straw and rice-straw are therefore promising candidates for the manufacture of MDF. [8]

9- Structure of straw

Annual plants as wheat and rice-straw are less homogenous than the perennial softwoods or hardwoods in the morphological structure. The straw is the structural material that makes the plant to stand up and is composed of the stem and leaves; the stem is divided into nodes and internodes, and the internodes are separated by the nodes at which the leaves are attached, see anatomy of a straw plant in Figure1.[8]

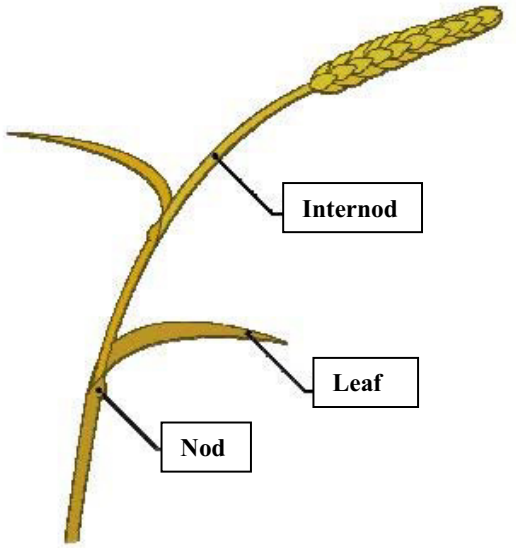

Figure1. Anatomy of the straw plant

9-1--Straw-based dry forming MDF process

The straw MDF process differs principally at the beginning of the MDF process as compared with the wood-based MDF. The difference is the dimensions of the raw materials. The straw length after harvesting is in the range of 0.3-0.5 m and the straw diameter is approximately 5 mm, depending on species. The wood-based raw materials are at least 10 times larger in size. Commercial production of straw MDF in full-scale mills does not exist today. Several attempts have been performed to produce straw panel boards and examples of particle board (PB) exist but not as conventional MDF where fibres are produced by pressurized defibration. One of the more famous examples is the strawboard manufacture at Isoboard. [9] Wheat-straw was the raw material and MDI resin was the applied adhesive. The Isoboard strawboard facilities was acquired by Dow BioProducts Ltd in 2001 and finally shut down in the year of 2006 due to low capacity. However, several pilot-plants for production of laboratory straw MDF are available; Bio Composite Center (Wales), Wilhelm-Klauditz-Institut, WKI (Germany), Washington State University, WSU (USA), and Alberta Research Council, ARC (Canada) are examples of institutes/universities equipped with necessary machines for production of MDF in pilot-scale. [9]

10-MDF ECO-board

Eco- board is the new generation MDF fiber board's 100 % environment friendly. ECO-boardsare not made from wood but uses agricultural fibers, residue or are left-over from harvests, a product that is usually burned as a waste problem. Using the advanced processing technology, the result is a board that is far superior to MDF or particleboards on the market today. Made of 100% high-quality natural rice straw Using formaldehyde-free adhesive (P-MDI) Produced in contionus hot pressing process. The straws used as the principal raw material of ECO board are deprived of strong toughness fiber in plant stems and are bonded by modified MDI which is straw binding-oriented. As a result,

our ECO board has both the advantages of the wood particle board and the medium density fiber board (MDF) making it the ideal upgrade product for traditional wood-based panel.

Besides releasing no formaldehyde, ECO board adopts straw fiber to replace lignified fiber creatively to have an excellent physical property outstripping ordinary artificial board.

- Resistance to Deformation

  Eco-friendly adhesive MDI has strong reactivity so that it can react with straw cellulose molecular to form firm irreversible new chemical bonds working as effective bonds inside the board. Due to the way that polymers combined together firmly and steadily.

  Moisture Resistance

  Large amount of natural wax layer on the surface of the straw fiber has a damp proof effect for Eco board like the paraffin additive in damp proof slab. In addition, MDI itself plays an important part in producing waterproof coating and sealant. After MDI reacting with straw fibers, the polymer composite structure formed in the reaction has pretty good hydrophobic property. Consequently, Eco board is not easy to absorb moisture. Furthermore, its volume expansibility after being affected with damp is superior to ordinary artificial boards.
- Fire Resistance

  Straw fiber contains a lot of silicon dioxide, which is a natural fire-proof material. Relevant test result also shows that our product, even in cases of adding no fire retardants, it could only become carbonized rather than spreading to other objects.
- Product processing performance

  With a versatile machining process performance: suitable of further processing such as perforation, tenoning, form milling, bending and carving, etc., Eco board has a homogeneous density, glossy surface, no obvious chromatic aberration and can be processed in a similar way, Eco board could be dealt with surface decoration including melamine veneering, single plate veneering, polyester paper veneering, fireproofing board veneering, PVC, paint and other plastic film coating process.

10-1-Why is it a sustainable material according to LEED criteria

It is made from straw and is a great alternative to other wood products. ECO-boardsare the wate product left after the usable parts of the plant (used as feed) are harvested. These straws would normally be taken to landfill or burned. [(10)] This products' a uniquely eco-sensitive building product; not only is it a rapidly renewable resource, since it is harvested on an annual basis, but turning the discarded stalks into a building material makes it recycled content as well.

10-2-Why does straw boards have no formaldehyde release?

Eco board, which puts an end to the history that all wood-based panels release formaldehyde, is a truly formaldehyde-free product. The straws used as the principal raw material of Eco-board are deprived of strong toughness fiber in plant stems and are bonded by modified MDI which is straw binding-oriented. As a result, our Eco-board has both the advantages of the wood particle board and the medium density fiber board (MDF) making it the ideal upgrade product for traditional wood-based panel. It is the key difference between Eco-board and ordinary artificial boards that to replace urea formaldehyde resin with modified MDI.

10-3-Discovered Eco board

The Eco-board has medium density, high strength, insulation, sound and heat insulation. Its surface is smooth, which is suitable to make fitting parts of partition wall and ceiling, acoustic panels veneered, decorative wall plates, container handling, closet, backdrop, television etc

Key features:

Superior workability: does not break when cut, easy trimming and exceptional bending properties.

Healthy: zero-emission formaldehyde-free adhesives and no noxious smells.
It is moisture, resistance and high durability.
Better water resistance than traditional wood-based board excellent nail-holding capacity on all sides.
Perfect abrasive resistance
Easy cleaning and maintenance

Table 1. Product specifications (according to Wanhua ECO_ board co.)

THICKNESS(MM)	WIDTH(MM)	LENGTH(MM)	DENSITY(KG/M³)
5	1220	2440	>750
9	1220	2440	>700-750
12	1220	2440	>700-750
15	1220	2440	>700-750
16	1220	2440	>700-750
18	1220	2440	>700-750
25	1220	2440	>700-750

Table 2. Product features (according to Wanhua ECO_ board co.)

Qualification items	Index Name
Percentage of Moisture (%)	4~13
Swelling rate of 2h (%)	≤8
Internal bonding strength(MPa)	≥0.35
Surface bonding strength(MPa)	≥0.8
Static bending strength(MPa)	≥13
Elastic Modulus(MPa)	≥1600
Nail-holding power of the Vertical Surface(N)	≥1100
Nail-holding power of the paralleling Surface(N)	≥700
Deviation of the average density (%)	≤±8
Formaldehyde Emission (mg/L)	0

11- A proposal to create a smaller wood production line for the manufacture of compressed ECO MDF boards by recycling rice straw in Menoufia, Egypt)

Since Egypt almost produces about five million tons of rice straw annually distributed to the governorates according to the 2014 as shown in table no 3, in the Delta governorates four million tons per year, and in Menoufia about 14802 tons a year where there are 5921 acres planted with rice in Menoufia and the acres of rice produced 2.5 tons of rice straw per year.
The proposed seeks to increase the environmental awareness and the state's attention of the problem and take a quickly steps to put a mechanism to deal with these solid waste in Egypt.

Table 3. Land area planted with rice in the Governorates in 2014[11]

Land area planted with rice in the Governorates in 2014	
Governorate	**Land area planted (acre)**
Sharqia	256336
Dakahlia	359700
gharbea	126815
Qalubia	9940
Kafr El-Sheikh	324628
El Behera	200237

Damietta	64724
Fayoum	2982
Ismailia	3956
Port Said	20178
Alexandria	3200
Menoufia	5921
Total	1378617

11-1- The current situation of MDF processing factories in Egypt and how to convert them to eco MDF boards free of urea formaldehyde

In Tanta there is a factory for the manufacture of MDF board from rice straw, it uses urea formaldehyde as a glue material. The use of this material is common in Egypt. Therefore; the proposal seeks to provide an environmental alternative to the ECO friendly glue material does not cause any harm. This proposal also do not generated any industrial waste affecting the environment, that waste resulting from the cutting process of the wood planks can be shredded and manufactured. This industry depends on a number of raw materials available in the local market and locally produced, that giving it the full domestic industry, which does not depend on any imported item.

11-2- A comparison between the current situation and the proposal submitted

Table 4. Comparison between the current situation and the proposal submitted

	current situation	proposal submitted
	Made of Rice straw obtained from the rice fields. the additive materials (100 kg urea formaldehyde – 30kg flour – 40 kg water)	Made of 100% high-quality natural rice straw Using formaldehyde-free adhesive(P-MDI) Produced in continues hot pressing process
Specifications	Causing damage to the environment due to the use of urea formaldehyde as a glue	An environmentally friendly product Eco board has both the advantages of the wood particle board and the medium density fiberboard (MDF) making it the ideal upgrade product for traditional wood-based panel.
Glue	urea formaldehyde	MDI
Thickness	16-18-22 mm	Thickness 5-12-15-16-18-22-36-40mm
Width	1220mm	1220mm
Length	2440mm	2440mm
Density	700-760	>700-750

11-3- MDI a sustainable glue used in ECO-boards

MDI provides a very strong bond with the wood particles as it reacts with the wood itself when put under intense heat, creating a chemical weld. It is a different and superior type of bond compared to the mechanical weld that formaldehyde based products produce. MDI resins contain no added formaldehyde (NAF) and are considered "exempt" under requirements of the California Air Resources Board (CARB) standards. Using MDI resins classifies products as both CARB I and CARB II compliant. The resins are also compliant to the European EPF-S standard, as well as the Japanese formaldehyde emission standard.

11-4- The Technical and Economic Elements of MDF boards

11-4-1-Manufacturing stages

A) The compilation of rice straw

It is seasonal stage is carried out during the harvest season, where rice straw are loaded by rams.

B) The storage phase

At this stage, straw has being stored in the stocks where there is the industrial security precautions to face the fire hazard and self-ignition. It must be emphasized the presence of water sprinklers distributed around the store to moisturize the stored material.

C) Grinding stage

The straw being chopping at a grinding degree required the final product quality increase by increasing the degree of milling process.

D) pressing stage

Pressing process is considered the basic process for the production of compressed wood panels and the process is done through a series of successive steps that can be summarized.

- Piston operation processing in order to run the heating circuit to raise the piston disc heat to 150 ° C, where it takes two or three hours depending on the ambient temperature.
- The processing of glue elements by mixing the following three vehicles by the weight ratios
  8-4-2- Packaging:
  Panels are stored on wooden flat base with dimensions 2.5 × 1.35 × 0.25 m horizontally placed in a well-ventilated place.

11-4-2- Quality components:

For the high quality of the product it has to be availability of hygiene conditions of storage sites so that insects or rodents do not exist, as well as to preserve the moisture ratios inside these places so as not to damage the product.

12- Applications of using ECO MDF boards in architecture and urban design

Application Areas	Application subsection
Furnishing	Children, Home and Office furniture; Cabinet and etc.
Construction fitments	Wall cabinet, window frame, door frame, hanging board, acoustic panel, partition wall, flooring, ceiling and interior door and etc.
Hardscape	Pedestrians, Seating decks, Pergolas, Retaining walls, wooden stalls and etc.

13- Conclusion

Potential new sources of materials using local raw materials available on the basis of the importance of environmental protection, rural development and farming community should be given priority. All this time, rice straw is considered a major agricultural waste and the cause of air pollution to the environment during harvesting are actually has a high economic value. Therefore, the use of straw wastes through the application of reusable agricultural wastes to create an Eco friendly material considered a sustainable process.

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